THE COSTS OF TSUNAMI FALSE ALARMS IN HAWAII

By Doak C. Cox

Contents

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SUMMARY

The following rough estimates of the annual costs of false alarms of the tsunami warning system in Hawaii are presented:

Immediate costs (response to individual false alarms)	per warning	per annum
Objectively analyzable	$327,000	$111,000
Other	450,000	153,000
Subtotal	$777,000	$264,000

Deferred costs (failure to respond to warnings because of previous false alarms)	Number per annum	Cost per annum
Deaths	0.34	$ 34,000
Other casualties	0.17	8
	0.51	$ 42,000

Total costs per annum $306,000

It is estimated that 80 per cent of these costs could be reduced by 80 per cent by a reduction in the frequency of false alarms. A research expenditure of $307,000 per year for 10 years would be justified to provide the basis for this reduction.

A. INTRODUCTION

Rough estimates of the costs of false tsunami warnings in Hawaii are presented in this paper as indicators of the benefits that may be anticipated from further tsunami research. The assistance of the Hawaii State Civil Defense Division in preparing the section on "The economic impact of [a single] false tsunami warning and in reviewing a draft of the section on "Potential improvements in public response" is gratefully acknowledged.

Other data, leads to data, or review comments on early drafts of this paper have been provided by:

W. T. Chow, Pacific Urban Studies and Planning Program and Geography Dept., Univ. Hawaii

Edward Fujii, Pacific Urban Studies and Planning Program and Dept. of Economics, Univ. Hawaii

Harold Loomis, Joint Tsunami Research Effort, Hawaii Inst. of Geophysics, Univ. Hawaii

Robert Schmitt, Hawaii Dept. of Planning and Economic Development

Gilbert White, Disaster Research Project, Institute of Behavioral Sciences, Univ. Colo.

David Okrent, Dept. Electrical Engineering, Univ. Calif. Los Angeles

The assistance of these persons is greatly appreciated. I must take primary responsibility, however, for the methods of estimation, the factors used in estimation, and the conclusions reached.

At best, the cost estimates are very rough. For reasons expressed at various points, I believe they are quite conservative--that is they are underestimates. The results of the analysis, it seems to me, have a clear value in indicating that a substantial level of tsunami research, conducted by such means and locations that it may be expected to result in reducing tsunami false alarms, is clearly justified. The paper may have some additional value as an elementary contribution to the realistic evaluation of tsunami hazard management.

It should be noted that the cost estimates presented here relate to Hawaii alone. Research resulting in reductions of false alarms will result in cost savings not only in Hawaii, but in other areas served by the Pacific Tsunami Warning System as well. It should also be noted that the estimates relate to costs of false alarms alone and not to other possible improvements in tsunami hazard management to which research would contribute.

I acknowledge especially the assistance of the Hawaii State Civil Defense Divison in estimating those immediate costs of false alarms that are objectively analyzable. The letter containing their estimates is included as an appendix to the paper.

B. IMMEDIATE COSTS

The immediate costs of a tsunami false alarm are the direct costs of the response to the warning. These costs include some that are objectively estimable and some whose estimate depends on a relatively subjective value assignment.

Objectively estimable costs

Objective, though no doubt crude, estimates of certain of the costs of tsunami warning have been prepared by the State Civil Defense Division (Appendix). The costs are those which would be incurred with a tsunami warning period of 3 hours duration occurring during normal working hours. Since it may be assumed that the predicted arrival times of tsunamis have a random distribution as to time of day, some adjustments are necessary. However, many of the operations affected are not limited to a 40-hour week, the effects of a warning in some operations begin well in advance of a formal warning, and mobilization and demobilization costs are independent of the duration of the warning period. In Table 1, each of the costs estimated by the Civil Defense Division is reestimated for an average tsunami false alarm, assuming that tsunami warning periods have a random distribution with respect to time of day.

Table 1. Objectively estimable costs of tsunami false alarms in Hawaii

Activities	Costs, $ thousand for warning occurring	
	During working hours	Random
Private Sector		
Waterfront operations	59	45
Small boats	15	15
Retail operations	36	30
Hotel evacuation	4	4
Evacuation of equipt. & vehicles	5	5
Small wholesale operations	5	3
Radio	6.5	6
Oil refinery	350	180
Total private sector	480.5	288
Government Sector		
State, other than schools	8	8
Schools	54.6	14
County	17	17
Total government sector	79.6	39
TOTAL	560.1	327

Other costs

The above costs do not include some that are not so amenable to objective analysis. The total defacto population within the area to be evacuated with a tsunami warning is on the order of 200,000. An evacuation of 3 hours duration thus involves something on the order of 600,000 man hours. We do not generally attempt to assign values to the activities of children in school, housewives, persons resting or performing recreational activities, etc. However, such activities are clearly regarded as valuable. Arbitrarily, a very conservative average estimate of $1 per man hour for such activities may be assigned. However, the activities of some of the population at risk are already included in the objective evaluation. Hence, rather than $600,000 a value of $450,000 may be assigned to the subjective supplementary costs of a tsunami warning.

Annual costs

To reduce the cost of individual tsunami false alarms to annual costs, it is necessary to assume the average frequency of false alarms. The frequency of tsunamis and potentially tsunamigenic earthquake seems to have been low in recent years, and hence the frequency of tsunami warnings, false or otherwise has been low. A better estimate of the normal frequency of warnings is probably provided by the record of 1948 through 1967 which I have previously summarized (Cox, 1968. The performance of the Seismic Sea Wave Warning System. Hawaii Institute of Geophysics HIG 68-2, 1962). In that 19-year period there were 18 tsunami warnings issued in Hawaii, including 13 false alarms (when there was either no tsunami or no significant tsunami effect on any coast in Hawaii). The false alarm frequency during this period was, thus, 0.68 per year.

However, it appears clear that a more extensive evaluation of the risk in Hawaii of each threatening tsunami is made now than was made prior to 1968, and that the ratio of false alarms to significant tsunamis and the frequency of false alarms in Hawaii are lower now as a consequence.

Quite arbitrarily, it is assumed that the average frequency of false alarms occurring on the basis of the present level of understanding and policy is half that of 1948 to 1967 or about 0.34 per year.

The annual costs of individual false alarms under present policy may then be estimated as shown in Table 2:

Table 2. Total immediate costs of tsunami false alarms in Hawaii

Nature of costs	Costs, $ thousand per warning	Costs, $ thousand per year
Objectively estimable	327	111
Other	450	153
Total	777	264

C. DEFERRED COSTS

Public response to warnings

It is quite clear that public confidence in the tsunami warning system is significantly decreased by a series of false alarms. No doubt the extent of the decrease on any occasion depends upon a number of factors including the number or frequency of previous false alarms, the level of inconvenience they have caused, the extent to which the public has considered them unavoidable, and the number or frequency of successful warnings. No exact measures are available of the extent to which the public fails to respond to a warning or the number of deaths that will result from the failure to respond, but the casualties that result from the failure, to the extent to which the failure is due to the history of false alarms, are indirect costs of the false alarms.

To obtain a rough estimate of the casualties that might be attributable to false alarms, a number of assumptions may be made:

1) The potential tsunami casualty rate (without a warning system) may be estimated from the historical casualty record after adjustment for population changes and for the effects of the warning system since its establishment in 1948.

2) The population at risk may be assumed proportional to the total defacto population of Hawaii.

3) The effects of an ideal warning system may be estimated through the use of a factor approaching 100 per cent for the reduction of casualties.

4) The effects of false alarms may be estimated by the use of factors varying with the ratio of false alarms to warnings of significant tsunamis.

Tsunami mortality potential

The most reliable historical record of deaths attributed to tsunamis is that compiled by Robert Schmitt (Catastrophic mortality in Hawaii. Hawaiian Journal of History 3:66-85, 1969). The deaths enumerated in column 2 of table 3 were taken from that source with two exceptions: the one death in 1957 that resulted from the crash of a plane carrying a reporter who was attempting to watch the tsunami waves as they arrived, and the two deaths that resulted from the local tsunami of 1975.

The population of Hawaii in the years when tsunamis caused deaths, shown in column 4 of the table, is also taken from a compilation by Schmitt (Historical Statistics of Hawaii, Univ. Press of Hawaii, in press). The figures shown for years later than 1946 are for defacto population, because the number of visitors present in the Islands was significant in those years.

Table 3. Tsunami mortality potential in Hawaii

(1) Year	(2) Tsunami origin	(3) Deaths	(4) Population (thousands)	(5) Mortality (°/₀₀)	(6) Warning system effec-tiveness	(7) Potential mortality (°/₀₀)	(8) Potential mortality distant tsunamis (°/₀₀)
1837	Chile	16	106	.151	0	.151	.151
1868	Local	46	61	.754	0	.754	
1877	Chile	5	56	.089	0	.089	.089
1923	Kamchatka	1	300	.003	0	.003	.003
1946	Aleutian	159	545	.292	0	.292	.292
1952	Kamchatka	0	520	.000	0.80	.000	.000
1957	Aleutian	1	591	.002	0.80	.010	.010
1960	Chile	57	651	.088	0.80	.440	.440
1975	Local	2	928	.002	0	.002	
Totals (139 yrs.)		287				1.741	.985
Potential mortality per year						.0125	.00709
Potential deaths per year at present population (952,000)						11.9	6.8

In column 6 it is assumed that the warning system was 80 per cent effective on the occasion of the 1952, 1957, and 1960 tsunamis, and accordingly, the potential mortality of these tsunamis is increased in column 7 by a factor of 5. It is assumed, however, that the warning system had no effectiveness on the occasion of the 1975 local tsunami.

The total of the potential mortalities in column 7 is divided by the period of record, 139 years, to provide an estimated potential mortality of .0125 per thousand population per year, and this, multiplied by the present population of 952,000, provides an estimated potential tsunami death rate of 11.9 per year.

Recognizing, however, that the Pacific Tsunami Warning System can have little effectiveness on the occasion of local tsunamis, the total of the potential mortalities, the potential mortality per year, and the potential rate of deaths per year, at present population, resulting from distant tsunamis alone, are indicated in column 8. The expectable death rate is 6.8 per year.

For several reasons, the estimate is probably conservative. Complete recording of the deaths of the tsunami of 1837 is very doubtful. A smaller fraction of the Hawaiian population was probably concentrated in the tsunami hazard zone between the 1850's and the 1960's than at present. No deaths resulted from the 1952 tsunami, and hence the calculation indicates no potential mortality, but there clearly was a significant population at risk in that year. The potential mortality of the 1957 tsunami was probably considerably higher than that calculated, for the same reason, although the one death that resulted from that tsunami clearly would not have been avoided by full effectiveness of the warning system.

Reduction of tsunami mortality by warning system

That deaths resulted from tsunamis in the period from 1948 to 1968, during which the Seismic Sea Wave Warning System was in operation, indicates that the warning system was not fully effective. It was assumed above that, with respect to tsunamis of distant origin, the warning system was 80 per cent effective during that period. Not all of the assumed 20 percent ineffectiveness can be attributed to the history of false alarms. It seems reasonable, however, to assume that half of the ineffectiveness might be attributed to this history.

The experience with the warning system since 1968 seems clearly to indicate that a policy of selective warnings based on regional evaluation of tsunami risk has been adopted, as was then recommended (Cox, D.C., the Performance of the Seismic Sea Wave Warning System, 1948-67. Hawaii Inst. of Geophysics, HIG 68-2, 79 pp, 1968. Also Cox, D.C. and H.B. Stewart, Jr., Technical Evaluation of the Seismic Sea Wave Warning System. The Great Alaska Earthquake of 1964: Oceanography and Coastal Engineering, Natnl. Acad. Sci., pp. 224-245, 1972).

Somewhat optimistically, perhaps, it may be estimated that the 10 per cent ineffectiveness attributable to false alarms has been reduced to 5 per cent by the improvements in understanding that have resulted from research and the change in policy. On this basis there remains a 5% ineffectiveness, with respect to mortality reduction resulting from false alarms, or 0.34 deaths per year.

Non-death casualty potential and reduction

The above estimation takes no account of tsunami casualties other than deaths. No exact figures for tsunami casualties other than deaths appear to be available for Hawaii, but conservatively they would probably be estimable at half the numbers of deaths or 3.4 potential non-death casualties per year. The remaining ineffectiveness of the warning system, atrributable for false alarms, with respect to non-death casualties, may then be estimated at 0.17 casualties per year.

Economic costs of tsunami casualties

The average annual costs of individual false alarms estimated in part B are economic costs. For comparability, the average annual tsunami mortality and casualty estimates presented in part C must be evaluated in economic terms.

The value of human life is often held to be incalculable. In actuality an estimation is implicit in every public expenditure intended to result in the saving of lives. As indicated in a number of studies, there is considerable inconsistency in such implicit expenditures. A 1967 analysis of the present value of the expectable future lifetime earnings of Americans, differentiated by age, sex, color, and educational level, provides one basis for an estimate (Rice, D. and B. Cooper, Economic value of human life. Amer. Journ. Publ. Health, pp. 1954-1966, 1967). Taking population distribution and life expectancy into account, it appears that the average would have been roughly $60,000 in 1967. Taking inflation into account the estimate would be about $100,000 now. I am informed (Okrent, David, *personal communication*) that some recent estimates of the value implicitly assigned by public policy to human life are somewhat lower (eg. $80,000) but other estimates of this value are larger by a factor of 2 or more (see eg. Conley, B.C., Amer. Econ. Rev. pp. 45-55, 1976). Hence the estimate of $100,000 seems conservative.

The corresponding benefit of the postulated reduction of 0.34 tsunami deaths per year even without making allowance for increases in population, would be $34,000 per year.

The evaluation of casualties other than deaths are no easier to estimate. Considering that they would include medical costs and the costs of subsequent care and lost productivity during the remaining life times of the persons injured, the average estimates of $50,000 per casualty or $8,500 for the 0.17 casualties per year seems conservative.

The estimates of potential casualty rates, casualty rates expectable under present policy, and associated economic costs are summarized in Table 4.

Table 4. Tsunami casualties and associated costs in Hawaii

Nature of casualties	Total Potential	Distant tsunami potential	Distant tsunami present	Attributable to false alarms	Casualty costs attributable to false alarms $thousand (rounded)
Deaths	11.9	6.8	.68	.34	34
Non-deaths	6.0	3.4	.34	.17	8
Total	17.9	10.2	1.02	.51	42

It should be recognized that the above estimate of justifiable research expenditure is based solely on the reduction of tsunami false alarms in Hawaii, and not on improvements in the tsunami warning system that would be effective elsewhere nor on other improvements in tsunami hazard management. Any research intended to result in the reduction of false alarms in Hawaii will undoubtedly result in other benefits.

No clear separation will be possible between research intended to result in warning system improvements and research intended to result in other improvements in tsunami hazard management, nor indeed between tsunami research and other related kinds of geophysical research. Nevertheless, it should be recognized that the efficacy of tsunami research with respect to improvements in the tsunami warning system will depend in part on the design of some of the research specifically for this purpose and the conduct of the research interactively with the potential users of the results.

D. TOTAL COSTS, REDUCIBLE COSTS AND RESEARCH SUPPORT IMPLICATIONS

Although the Hawaiian use of the National Flood Insurance Program may control increases in the population within the zone of potential tsunami inundation, it seems unlikely that the population at risk will be reduced. Hence it may be assumed that the costs of tsunami false alarms estimated in the previous parts of this paper will continue indefinitely in the future unless the results of further research make possible the reduction of false alarm frequency, and until such results are incorporated in warning system policy.

Total elimination of false alarms cannot, of course be expected, but a substantial reduction should be possible. What are regarded by the public in Hawaii as false alarms are warnings of tsunami which were either not generated or turned out not to have readily observable effects in Hawaii. Most tsunamis that involve a significant risk to people at any place in Hawaii are readily observable at a large number of places on the Hawaiian costs. Hence there is a significant margin between those tsunamis for which warning should be suppressed, because they would be considered false alarms, and those for which warnings should clearly be issued because they involve a significant risk to persons.

There can, of course, be no certainty, how much reduction in the frequency of false alarms might be achieved through the application of the results of a research program. I believe, however, that it is reasonable to assume that an 80 per cent reduction in the costs of false alarms might be achieved through the application of the results of research in a fairly brief period in the future, no more than say 5 or 10 years.

A justifiable level of research expenditure is one which, cumulated with interest at the end of the research period, will amount to an investment on which the interest would equal the annual benefits to be achieved by the research.

In Table 5 are summarized the total annual costs of tsunami false alarms, the reducible part of these costs, assuming 80 per cent reduction, the justified research investment assuming a 6 per cent interest rate, and the justified annual research expenditure assuming a 6 per cent interest rate and a 10 year research period.

Table 5. Total and reducible costs of tsunami false alarms in Hawaii and research investment justified to effect reduction

Nature of cost	($ thousand) Total annual cost	Reducible annual cost	Total justified research investment	Justified annual research expenditures
Immediate	264	211		
Deferred	42	34		
Total	306	245	4083	307

APPENDIX

GEORGE R. ARIYOSHI
GOVERNOR

MAJOR GENERAL VALENTINE A. SIEFERMANN
DIRECTOR OF CIVIL DEFENSE

PHONE 734-2161

STATE OF HAWAII
DEPARTMENT OF DEFENSE
OFFICE OF THE DIRECTOR OF CIVIL DEFENSE
FORT RUGER
HONOLULU, HAWAII 96816

January 27, 1977

HICDIE

Dr. Doak C. Cox, Director
Environmental Center
University of Hawaii
2540 Maile Way, Building 10
Honolulu, Hawaii 96822

Dear Dr. Cox:

The following cost factors represent the estimated economic impact on the more visible activities in the State of Hawaii that would be directly affected by a false tsunami warning. They are not intended to display an estimate of total man-hours of productivity or value of goods and services lost as the direct result of such a warning which would be a much larger figure.

The basic information reflected here was obtained from business associations, industries and government agencies based on the assumption that a false warning involving a three-hour time frame would occur during a normal working day.

Private Sector:

1.	Waterfront operations close down, loading and unloading of cargo ceases. Costs involved idling of ships and nonproductive labor force. No costs assessed for loss of equipment productivity.	$ 59,000
2.	Small boats in coastal marinas evacuate or owners secure moorings and take necessary protective actions.	15,000
3.	Retail operations - shops, bars, restaurants, etc. - close or drastically curtail operations. Estimate based on lost sales due to closing and/or anticipated lack of activity during the warning period.	36,000

4.	Hotels evacuate guests vertically to higher floors or, in the case of small hotels, from the inundation area. Estimates involve lost productivity of employees and costs to resume normal activities.	$ 4,000
5.	Equipment and vehicles in inundation areas evacuated.	5,000
6.	Small wholesale, storage, production and processing activities curtailed or secured operations and evacuated.	5,000
7.	Civ-Alert radio operations during a two-hour period of intense public information announcements. Estimate represents loss of advertising income for 33 stations.	6,500
8.	Oil refineries in Campbell Industrial Park drastically curtailed or cease operations. Estimate represents cost of loss productivity of approximately 150,000 bbls. of product. No cost assessed for idling facilities.	350,000
	Estimated Private Sector Costs.....	$ 480,500

Government:

State government

1.	Estimate based on 240 State employees that would cease operations in harbors and inundation areas or cease their normal departmental functions to participate in emergency civil defense operations. Loss of productivity only.	$ 8,000
2.	There are 14 schools in the tsunami inundation areas of the State that require the evacuation of 17,525 students and 1,820 staff members. It would be difficult to estimate loss of student time, therefore, estimate is based on staff loss of productivity only.	54,600

County government

Estimate based on police, fire and other county agency overtime costs and loss of productivity of county employees involved with county civil defense operations.	$ 17,000
Estimated Total State and County Government Costs.....	$ 79,600

(Note: Federal government costs not included)

Estimated Total Costs..... $ 560,100

Sincerely,

[redacted]

[redacted] JAMES T. McCLELLAN
Vice Director of Civil Defense